

Chapter 8 Drinking water treatment chemicals



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Endorsed NHMRC – September 2005, NRMCC - September 2006.

8.1 Introduction

The production of safe reticulated drinking water is vital for society. In recent decades, there have been numerous examples throughout the world of poor water quality impacting adversely on human health. Such episodes are rare in Australia, but the dire consequences of compromised disinfection and blooms of cyanobacteria serve to remind us of the need for drinking water treatment.

Addition of chemicals to make water safe for consumption is widely practiced by the water industry and has generally been accepted by the community. However, safeguards must be sufficient to ensure that any residual amount of these chemicals, byproducts of their reactivity or minor contaminants in their formulations do not pose an unacceptable health risk.

Treatment chemicals are added to drinking water mainly to reduce or eliminate the incidence of waterborne disease, for other public health measures, and to improve the aesthetic quality of the water. Any chemical used in, on, or near drinking water sources, or used during the treatment of drinking water should:

- be effective for the desired outcome
- not present a public health concern
- not result in the chemical, its byproducts or any contaminants exceeding drinking water guideline values.

This chapter provides guidance on chemicals used during the storage, treatment, and distribution of drinking water, quality assurance procedures, and the requirements for gaining approval for these chemicals.

8.2 Scope and limit of application of this chapter

Chemicals used near water for purposes other than direct improvement of water quality are not considered as drinking water treatment chemicals. Such chemicals include fertilisers and other agricultural chemicals used in properties adjacent to water storages, herbicides used to reduce vegetation along waterways, and pesticides used to control mosquitoes and other disease vectors in water storages. Use of these chemicals near raw water sources should be carefully considered, and the risks associated with their use should be minimised to ensure that water quality and public health are not jeopardised. Further information on these chemicals is given in Section 6.3.3 and in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (NWQMS 2000).

This chapter does not cover the specialised chemicals used in water treatment for non-potable uses (e.g. chemicals used in industrial boilers and air conditioning cooling towers), nor does it cover the impact on water quality of materials in direct contact with water. Information on these chemicals and impacts is given in Australian Standards AS3666.1:2002 — *Air handling and water systems of buildings Microbial control – design, installation and commissioning*; AS5667.7:1998 — *Water quality – Guidance on sampling of water and steam in boiler plants*; and AS4020:2002 — *Testing of products for use in contact with drinking water* respectively.

Information on occupational exposure to drinking water treatment chemicals resulting from their manufacture, transportation or use should be obtained from the manufacturer and Material Safety Data Sheets (MSDS), or from the appropriate State or Territory Occupational Health and Safety Authority (see Section 8.9).

8.3 Overview of chemical treatment processes

In the production of drinking water, a number of different chemicals may be added to the water. The types and quantities of chemicals can vary widely and will depend on a range of factors including raw water quality, treatment processes employed and treated water quality objectives. Chemical treatment processes are used to:

- control algae
- remove turbidity and colour
- remove microorganisms
- remove algal metabolites and synthetic pollutants
- reduce organic matter
- reduce the concentration of iron, manganese and other elements
- reduce pesticides and herbicides
- control taste and odour
- soften
- buffer or modify the pH
- disinfect
- control corrosion in distribution systems.

Chemical treatments may also be used for other public health measures, including:

- fluoridation (to prevent dental caries)

The following sections outline common processes employed in water treatment to achieve these objectives.

8.3.1 CONTROL OF ALGAE

Algicides are used to reduce toxic or odorous algal blooms in water reservoirs. The chemical commonly used in the management of algal growth is copper sulfate. Before an algicide is used, the possible effects on aquatic biota, the accumulation of copper in sediments, the potential impacts on downstream treatment processes and final treated water quality should be considered.

The use of copper as an algicide is controlled in some States. Information on the use of these chemicals should be obtained from the appropriate State or Territory authority (see Section 8.9).

8.3.2 COAGULATION AND FLOCCULATION

The primary use of coagulant and flocculant chemicals is in the removal of suspended and colloidal solids such as clays. Coagulation is particularly important in the treatment of surface waters. Removal of the solids is achieved by aggregating fine suspended matter into larger flocs. Coagulant and flocculant chemicals will also remove some natural organic matter, colour and microorganisms (e.g. bacteria, viruses and algae). The size and strength of the floc can be controlled and modified, depending on the treatment process in use, and the floc can be removed by sedimentation and filtration.

8.3.3 ADSORPTION

Adsorption is primarily used to improve water quality through the accumulation of substances at the interface between two phases, such as a liquid and a solid, due to chemical and physicochemical interactions. The solid on which adsorption occurs is called the adsorbent. Activated carbon is an excellent adsorbent.

Adsorption is commonly used to remove organic contaminants such as herbicides, pesticides, algal toxins and metabolites; it is also used to remove compounds which may impact on the taste and odour of water.

8.3.4 SOFTENING

Softening is undertaken as part of water treatment to remove calcium and magnesium salts, particularly carbonates and bicarbonates, which cause water hardness. Hard water can cause scale build-up on water heating elements and can cause problems with the use of soaps and detergents. Softening very hard waters can also lead to high concentrations of sodium in water. While this may possibly give the water a salty taste, it is unlikely to present a health concern. Water that is too soft can be corrosive, which may occur when reverse osmosis is being used for water treatment, in which case it may be necessary to restore some hardness to prevent corrosion.

8.3.5 OXIDATION

Various oxidants may be added to water to oxidise problem compounds. For example, chlorine or potassium permanganate may be added to control iron and manganese. The oxidised forms of iron and manganese are readily removed by coagulation, flocculation and filtration. Oxidants may also be used to oxidise compounds which impact on the taste and odour of water, and organic contaminants such as pesticides.

Ozone, and possibly hydrogen peroxide, may be added to oxidise organic compounds, and thus reduce the amount of coagulant required. Adding these chemicals also helps to reduce the length of long-chain organic molecules, which are then more effectively removed by granular activated carbon.

8.3.6 DISINFECTION

Disinfection of water is generally used either alone or as the final step in water treatment, after clarification or filtration. Disinfection is widely used to prevent the passage of bacteria, viruses and some protozoa into the distribution system. Typical chemicals used for disinfection of drinking water supplies are strong oxidants, such as chlorine (and its derivatives, chlorine dioxide and chloramine), ozone and hydrogen peroxide.

The efficiency of disinfection depends greatly on the quality of the source or treated water, and can also be strongly affected by conditions such as chemical contact time, the pH and turbidity of the water, and organic content of the water.

The aim of treatment processes used before disinfection should be to produce water with the lowest possible turbidity and organic content. Excessive particulate matter in the water can protect microorganisms from the action of disinfection chemicals. Also, excess organic matter and other oxidisable compounds in water can react with disinfection chemicals intended to inactivate microorganisms and can result in an increase in the formation of disinfection byproducts (see Section 6.3.2 for general information on disinfection byproducts, and the fact sheets in Section V for information on specific byproducts). Best practice operation of a conventional water treatment plant should be able to produce treated water with a turbidity of less than 0.1 nephelometric turbidity units (NTU).

8.3.7 ADJUSTMENT OF PH

Adjustment of pH is important in drinking water treatment processes such as coagulation (particularly for the removal of natural organic matter), corrosion control and softening.

Control of pH is also important for effective disinfection and for minimising the formation of disinfection byproducts. The efficiency of certain disinfectants is strongly dependent on pH.

8.3.8 ADDITION OF BUFFERING CAPACITY

Soft waters can be subject to pH change as they travel through the distribution system. The rate of change depends on a number of factors including the water hardness, pipe materials used (e.g. cement lined pipe), the contact time, temperature. Increasing the buffering capacity of the water can help control the rate of change of pH through the distribution system.

8.3.9 CORROSION INHIBITION

The mechanisms of corrosion in a water distribution system are complex, and involve an interrelated combination of physical, chemical and biological processes. These depend greatly on the materials used within the distribution system and the chemical properties of the water, particularly its buffering capacity. Water corrosivity can be minimised by adjustment of pH and increasing calcium carbonate hardness (resulting in a positive Langelier index). Corrosion can also be reduced by maintaining disinfection residual throughout the distribution system.

Corrosion inhibition chemicals (such as sequestering agents) are used to reduce corrosion of pipes and household services. They also control the build-up of scale deposits from the dissolved mineral content of drinking water. This is achieved through the addition of chemicals that form a protective film on the surface of pipes. While corrosion inhibitors reduce corrosion, limit metal solubility or convert one form of corrosion to another (e.g. alleviating tuberculation and replacing it with more uniform corrosion), they do not totally prevent corrosion.

8.4 Public Health Measures

8.4.1. FLUORIDATION

Fluoridation of drinking water is not a water treatment process, but has been and continues to be effective in reducing the incidence of dental caries. It has many advantages over alternative methods for fluoridation, due to its cost effectiveness, consistency of exposure, equal distribution to all socioeconomic groups, and safety. In some areas, fluoride can occur naturally in drinking water.

In areas where the drinking water supply is artificially fluoridated (at the instigation of the relevant State or Territory health authorities), the process is generally undertaken after clarification and chlorination of the water, because fluoride ions may adsorb onto the surface of suspended matter in the water and be subsequently removed through these processes. Fluoridation is generally achieved by adding either a slurry of sodium fluorosilicate, a solution of hydrofluorosilicic acid or (less commonly) a saturated solution of sodium fluoride, added as a metered dose for a given rate of water flow. Correction of pH may need to be carried out after fluoride addition. Use of fluoride is controlled by State and Territory legislation and regulations, and local regulations. Some of these are outlined in Table 8.1 (see also Section 8.9).

Table 8.1 State and Territory fluoride legislation and regulations

Australian Capital Territory	• <i>Electricity and Water (amendment) Act (no 2) 1989</i> . No 13 of 1989—Section 13
New South Wales	• Fluoridation of Public Water Supplies Regulation 2002. < www.legislation.nsw.gov.au > • <i>Fluoridation of Public Water Supplies Act 1957</i>
Northern Territory	• <i>Dental Act Schedule 3 1999</i>
Queensland	• Fluoridation of Public Water Supplies Regulation 1998. Reprinted as in force on 4 January 1999 • <i>Fluoridation of Public Water Supplies Act 1963</i> . Reprinted as in force on 21 December 1998
South Australia	• There is no fluoride legislation in South Australia
Tasmania	• <i>Fluoridation Act 1968</i>
Victoria	• <i>Health (Fluoridation) Act 1973</i>
Western Australia	• <i>Fluoridation of Public Water Supplies Act 1966</i>

8.5 Assessment of chemicals acceptable for use in drinking water treatment

8.5.1 CHEMICALS PREVIOUSLY ASSESSED

The NHMRC has examined a wide range of chemicals for treating water in Australia. To be acceptable, the chemical must have a practical application (e.g. clarify dirty water, or destroy or inactivate harmful microorganisms). The chemical must achieve its purpose and must not be toxic when ingested at concentrations present in treated water.

A drinking water treatment chemical is considered suitable for use when used in accordance with standard operating procedures.

This does not relieve a water authority from having risk control measures in place to ensure the effectiveness of a particular chemical in a water treatment process. For example controls need to be in place to prevent over- or under-dosing. Water treatment systems also need to be designed to ensure that residuals and contaminants from multiple treatment chemicals added will not exceed recommended guideline values at the consumer's tap.

The potential for a chemical to interact with any other added chemical or other compounds present in the water also needs to be considered.

The chemicals listed in Table 8.2 are considered by the NHMRC to be suitable for use in the treatment of drinking water.

If a chemical not listed in this chapter is to be used in the treatment of drinking water, it is the responsibility of the water authority to seek advice from the appropriate state/territory health regulatory agency, and take into consideration health, environmental, and occupational health and safety issues.

The fact sheets in Section V provide detailed information on chemicals used in the treatment of drinking water.

Table 8.2 Chemicals recommended for use in the treatment of drinking water

<i>Treatment chemical</i>	<i>Formula</i>	<i>Original date of approval by NHMRC</i>	<i>Uses</i>
Aluminium chlorohydrates	$AlCl(OH)_3$	2005	Coagulation
Aluminium sulfate (alum)	$Al_2(SO_4)_3$	1983	Coagulation
Ammonia	$NH_{3\text{ aq}}$	1983	Generation of chloramines for disinfection
Ammonium sulfate	$(NH_4)_2SO_4$	1983	Generation of chloramines for disinfection
Calcium hydroxide (hydrated lime)	$Ca(OH)_2$	1983	pH correction Softening Corrosion control
Calcium hypochlorite	$Ca(OCl)_2$	1983	Disinfection/oxidation
Calcium oxide (quick lime)	CaO	1983	Coagulation aid pH correction Softening Corrosion control
Carbon, powdered activated/ granulated activated (PAC/GAC)	C	1983	Adsorption
Chlorine	Cl_2	1983	Disinfection/oxidation
Chlorine dioxide	ClO_2	2005	Disinfection/oxidation
Copper sulfate	$CuSO_4$	1983	Algicide

Table 8.2 Chemicals recommended for use in the treatment of drinking water (continued)

Treatment chemical	Formula	Original date of approval by NHMRC	Uses
Ferric chloride	FeCl ₃	1983	Coagulation
Ferric sulfates	Fe ₂ (SO ₄) ₃	1983	Coagulation
Hydrochloric acid	HCl	2005	pH correction
Hydrofluorosilicic acid (fluorosilicic acid)	H ₂ SiF ₆	1983	Fluoridation
Hydrogen peroxide	H ₂ O ₂	1983	Disinfection Oxidation
Hydroxylated ferric sulfate		2005	Coagulation
Ozone	O ₃	2005	Disinfection/oxidation
Polyacrylamides	(C ₃ H ₅ NO) _n	1977	Coagulation aid Flocculation aid Filter aid
Polyaluminium chlorides	Al _n (OH) _m Cl _(3n-m)	1979	Coagulation
Poly aluminium silica sulfates	Na ₁₂ (AlO ₂) (SiO ₂) ₁₂ ·xH ₂ O	2005	Coagulation
Polydiallyldimethylammonium chlorides (polyDADMACs)		1982	Coagulation and coagulation aid
Potassium permanganate	KMnO ₄	1983	Disinfection/oxidation
Sodium aluminates	NaAlO ₂	1983	Coagulation
Sodium bicarbonate	NaHCO ₃	1983	pH correction Softening Corrosion control
Sodium carbonate (soda ash)	Na ₂ CO ₃	1983	pH correction Softening Corrosion control
Sodium fluoride	NaF	1983	Fluoridation
Sodium fluorosilicate	Na ₂ SiF ₆	1983	Fluoridation
Sodium hexametaphosphate	(NaPO ₃) _x	1983	Corrosion control
Sodium hydroxide (caustic soda)	NaOH	1983	pH correction Softening Corrosion control
Sodium hypochlorite	NaClO	1983	Disinfection/oxidation
Sodium silicate	Na ₂ SiO ₃	1983	Coagulation aid Flocculation aid pH correction Corrosion control
Sodium tripolyphosphate	Na ₅ P ₃ O ₁₀	2005	Corrosion control Softening
Sulfuric acid	H ₂ SO ₄	1983	pH correction
Zinc orthophosphate	Zn ₃ (PO ₄) ₂	1987	Corrosion control

8.5.2 ASSESSMENT OF NEW WATER TREATMENT CHEMICALS

The procedure to gain approval by NHMRC for new drinking water treatment chemicals for use in Australia is undertaken on a case-by-case basis. Sponsors of a new water treatment chemical seeking inclusion of the chemical into the NHMRC *Australian Drinking Water Guidelines* should, in the first instance, contact the NHMRC. A comprehensive assessment of toxicological information will be required as part of the approval process.

National procedures established by the National Industrial Chemicals Notification and Assessment Scheme (NICNAS)¹ are followed when assessing existing chemicals, assessing a new use for an existing chemical or assessing new drinking water treatment chemicals for use in Australia. NICNAS reviews of toxicological data, undertaken through a cost-recovery arrangement with the sponsor of the chemical, are required prior to final consideration by the NHMRC.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) are responsible for safety and efficacy assessment and registration of pesticides and veterinary medicines (including algicides).

8.6 Quality assurance for drinking water treatment chemicals

8.6.1 RISKS ASSOCIATED WITH DRINKING WATER CHEMICALS

A cornerstone of the management of drinking water quality (see chapters 2 and 3) is the analysis of hazards and the management of risk.

The intentional addition of chemicals to water intended for drinking purposes carries with it a potential risk. This may result from any of the following:

- the toxicological properties of the chemical itself
- underdosing or overdosing of the chemical
- contaminants in the chemical arising from the manufacturing process or the raw materials used
- contaminants in the chemical arising during transport, storage and use on site
- byproducts formed through the use of the chemical.

Contamination of chemicals can be minimised by the use of good manufacturing practice, which uses quality control and quality assurance programs to maximise product purity. The purity of chemicals used in Australia for the treatment of drinking water supplies will vary depending on the manufacturing process. Contaminants that may occur in specific treatment chemicals are outlined in the fact sheets (see Section V). The information in the fact sheets is based on the best available data at the time of publication. However, research and industry experience may lead to changes in manufacturing processes or better understanding of the properties of the chemicals, which in turn may lead to changes in procedures for how water treatment chemicals should be handled, stored and used.

8.6.2 MANAGING RISKS

A complete water quality management program needs to recognise any potential risks from use of drinking water treatment chemicals and include strategies to manage them appropriately. These risks should be minimised by the implementation of a quality assurance system for the management of production, supply, delivery and use of water treatment chemicals.

The first step in managing the risk associated with the use of drinking water treatment chemicals is to ensure that the chemicals supplied meet a minimum standard, as established by the relevant State or Territory regulatory agency. For example, water authorities may formally specify the strength of active ingredient and acceptable contaminant levels in each drinking water treatment chemical (see Section 8.6.3). However, this in itself will not adequately control the risk. The contractual requirement should be supported by batch-testing data provided by the supplier from an independent NATA (National

¹ <http://www.nicnas.gov.au/>

Association of Testing Authorities) accredited laboratory, and random testing carried out by the water authority itself. Chemicals should not be accepted for delivery unless a batch analysis certificate has been obtained and checked by the water authority.

Formal accreditation of the manufacturing facility by an independent accreditation agency (e.g. the International Organization for Standardization (ISO) or NSF International) provides a further level of risk management. Such accreditation should include random site visits to the manufacturing facilities by the relevant regulatory agency and, if warranted, the water authority.

Chemical suppliers should be evaluated and selected on their ability to supply products in accordance with required specifications. Documented procedures for the control of chemicals, including purchasing, verification, handling, storage and maintenance should be established to assure the quality of the chemical at the point of application (see Section 3.10.1). Responsibilities for testing and quality assurance of chemicals (supplier, purchaser or both) should be clearly defined in purchase contracts.

An important step in a quality assurance system for chemical addition to drinking water is to ensure that the required chemical is of the specified quality, and specified strength, and is delivered into the correct storage vessel, at the correct site at the correct time. This is necessary to:

- ensure that the correct chemical at the required concentration is used in drinking water treatment
- ensure that cross contamination of storages does not occur
- ensure inappropriate and unsafe mixing of chemicals does not occur
- help to ensure the health and well being of staff and contractors during the delivery and dosing process.

Broadly, the objective of the water treatment chemical quality assurance system is to manage all the factors associated with the specification, contract management, supply, storage, use and handling of water treatment chemicals that could adversely impact upon the health and wellbeing of staff, contractors and consumers. Box 8.1 outlines the components that make up an effective quality assurance system for drinking water treatment chemicals.

Box 8.1 *Desirable components of a quality assurance system*

The desirable components of a quality assurance system for chemicals used in the production of drinking water may include:

- Selection of chemical suppliers based on capability to meet specified requirements for supply and delivery, monitoring and analytical testing of contaminants.
- Selection of suppliers with a quality management system that is certified by an independent accreditation agency.
- An appropriate monitoring program to ensure compliance of chemicals with specifications.
- An audit process for the supplier's manufacturing, storage and delivery processes.
- A formal checklist for the dispatch and delivery process.
- A delivery driver induction system for each site, with each driver inducted onto each site and appropriate record keeping procedures.
- The provision of details of the delivery site (site photographs may be useful).
- An identity check directly linking the delivery driver to the chemical company.
- The clear identification and labelling of chemical storage vessels, filling points and delivery pipe work at all sites (locks on filling points are desirable).
- A requirement that chemicals should only be delivered when an appropriate water authority staff member is present to check documentation including batch analysis certification and ensure unloading to the correct storage vessel.
- A standard operating procedure for the delivery and receipt of chemicals at each delivery site including a documented acceptance criteria system to assist site operations staff in assessing whether to accept or reject the delivery of a chemical.
- A gross visual check of the chemical and, where appropriate, simple physical testing by the water authority representative at the delivery site before unloading.
- A check by both parties that the delivery vessel is being connected to the correct storage vessel.
- A check that appropriate personal protective equipment is being worn, and that relevant health and safety requirements are being addressed.
- Appropriate recording and storage of relevant documentation.
- A system to ensure that any spillage associated with the delivery process is contained and does not escape to the environment.
- An emergency procedure in the event of possible systems failure or human error.

The combination of a chemical quality assurance system and a delivery and storage quality assurance system such as those outlined in Box 8.1 can significantly reduce risks to all stakeholders. The combined system should include formal quality audits (see Section 3.11).

8.6.3 SPECIFICATIONS FOR THE SUPPLY OF DRINKING WATER TREATMENT CHEMICALS

The preparation of specifications for a chemical supply contract can be a time consuming and difficult task. Documents should be prepared in conjunction with a risk assessment and controls recommended in Sections 8.5.1 and 8.5.2.

To simplify the process for water authority staff preparing their own specifications, an example specification for the supply and delivery of liquid aluminium sulfate (Al_2SO_4) to a water authority is provided in Box 8.2.

The specification includes details on the required content of aluminium which is often, but not always, expressed as equivalent aluminium oxide (Al_2O_3), product clarity, solids content and pH as well as specific impurity limits. The specification also details some delivery and acceptance criteria. Product strengths and basic characteristics of the chemicals can be obtained from the Drinking Water Chemical Fact Sheets in Section V. The water authority may customise these specifications to suit their particular situations and risks.

The Specification should also clearly define the arrangements and responsibilities for ensuring the treatment chemical is not contaminated during transport or storage prior to transport.

Box 8.2 Example specification for the supply and delivery of liquid alum to a water authority

ALUMINIUM SULFATE (ALUM)– SPECIFICATION REFERENCE

This specification is for the supply and delivery of liquid aluminium sulfate ($\text{Al}_2(\text{SO}_4)_3 \cdot 14\text{H}_2\text{O}$) to [Name of water authority] Sites. This specification is based on the NHMRC *Australian Drinking Water Guidelines* (2004), the American Water Works Association Standard for Aluminium sulfate – liquid, ground or lump (ANSI/AWWA B403-93) and the Water Chemicals Codex (NRC, 1982).

Liquid aluminium sulfate is not currently listed as Dangerous Goods.

REQUIREMENTS

Material Safety Data Sheets (MSDS)

The successful Tenderer must supply a current MSDS with a review date not exceeding five (5) years. The MSDS must, as a minimum, comply with the requirements of the National Occupational Health and Safety Council (NOHSC) MSDS Guidelines. Whilst the NOHSC-MSDS format is preferred, alternative formats exceeding the level of information required by NOHSC-MSDS Guidelines are acceptable.

Liquid aluminium sulfate clarity

Liquid aluminium sulfate shall be of such clarity as to permit the reading of flow measuring devices without difficulty.

Content of aluminium

The water soluble aluminium content of liquid aluminium sulfate is expected to be greater than or equal to 4.23% of Al, or to fall within the range of 7.5 to 8.0 % as $\text{Al}_2(\text{SO}_4)_3$.

Suspended Solids

In liquid aluminium sulfate, it is expected that the level of suspended solids is below 0.2%.

pH

The pH of liquid aluminium sulfate is expected to fall within the range of 2.3 to 2.8 pH units.

Specific Impurity Limits

It is expected that the total water-soluble iron (expressed as Fe_2O_3) content of liquid aluminium sulfate shall be no more than 0.35%. The level of contamination of the liquid aluminium sulfate shall be such that compliance with the recommended maximum impurity content (RMIC) values from Table 8.4 in the NHMRC *Australian Drinking Water Guidelines* is achieved. The RMICs, in mg/kg, for $\text{Al}_2(\text{SO}_4)_3$ are:

Box 8.2 Example specification for the supply and delivery of liquid alum to a water authority (continued)

Impurity	Dose: 20 mg/L	Dose: 60 mg/L	Dose: 120 mg/L
Arsenic	16.5	5.5	2.7
Cadmium	4.7	1.6	0.8
Chromium	117.5	39.2	19.6
Lead	23.5	7.8	3.9
Mercury	2.4	0.8	0.4
Selenium	23.5	7.8	3.9
Silver	235	78	39

VERIFICATION**Quality Assurance**

The supplier is expected to possess a Quality System that facilitates the tracking of product from raw material to delivery. [Name of water authority] may audit this Quality System to verify the correctness of information relating to the purchased product. In addition, [Name of water authority] may sample the purchased product at the point of destination to verify the quality of the supplied product.

Liquid Alum Samples

If [Name of water authority] elects to sample the product at the point of destination, the sampling procedure outlined in the American Water Works Association Standard for Aluminium Sulfate – Liquid, Ground, or Lump (ANSI/AWWA B403-93) will apply.

Nonconforming Product

If [Name of water authority] discovers that the aluminium sulfate delivered does not meet the requirements of this specification, a notice of nonconformance will be issued to the supplier through the [Name of water authority]'s Quality System, within ten working days of the receipt of the goods.

A nonconformance will also be issued if deficiencies are detected during any audit of the supplier's Quality System.

DELIVERY**Liquid**

Marking, packaging and shipping of aluminium sulfate shall comply with AS 3780-1994 *The Storage and handling of corrosive substances*, and current federal, State, Territory, and local regulations.

The carrying vessel shall be in a suitable condition for hauling liquid aluminium sulfate and shall not contain any substances that might affect the use or usefulness of the liquid aluminium sulfate in treating potable water or in treating wastewater.

Contamination

Bulk or semi-bulk containers shall be carefully inspected prior to loading of the chemical by the supplier to ensure no contaminating material exists.

The supplier must have a system in place to ensure that liquid aluminium sulfate is not contaminated by any other product. This may involve implementing a specific cleaning regime between loads or the dedication of tankers or containers to only one type of product.

Certificate of Weight

[Name of water authority] may require that weight certificates accompany bulk shipments from a certified weigher or [Name of water authority] may check the weights on delivery.

Affidavit of Compliance

[Name of water authority] requires an affidavit from the manufacturer or supplier that the aluminium sulfate furnished according to [Name of water authority]'s order complies with all applicable requirements of this specification. [Name of water authority] also requires that the supplier provide a certified analysis of the aluminium sulfate. [Name of water authority] may also elect to use in-house analytical equipment to analyse the product to ensure compliance with this specification.

Documentation

A copy of the order, the delivery docket, and the affidavit of compliance and/or the record of certified analysis will accompany the delivery of aluminium sulfate. This documentation shall be left in an appropriate location at the delivery point.

Further, a copy of the delivery docket is to accompany the invoice (with references to the delivery docket number), and forwarded to [Name of water authority]'s Accounts Department to facilitate timely payment of accounts.

8.7 Monitoring and analytical requirements

A quality-controlled system for management of drinking water treatment chemicals should be supported by appropriate testing and monitoring.

All chemicals used in water treatment should be tested, to check both the concentration of the active ingredients and the presence of contaminants relative to a specification. This is to ensure that the effectiveness of the treatment process, the quality of the water and the integrity of the assets are not compromised.

Requirements for testing by the manufacturer should be clearly defined in the specification, including testing methods. The amount, type of testing and whether NATA certified results from an external laboratory are required may need to be negotiated to achieve a solution that is both effective and affordable. Clear statements as to the testing methods should be included in the specification. The specification should require test results to be available prior to the chemical delivery being unloaded at the water authority's plant to allow operational staff on site to reject delivery if specified requirements are not met.

Various physical characteristics can also be examined as part of the quality assurance program. Table 8.3 lists simple suggested acceptance criteria for some water treatment chemicals that could be applied by operational staff on site at the treatment plant. These criteria rely on human senses or simple equipment.

Table 8.3 Acceptance criteria for some water treatment chemicals

Chemical	Tests	Acceptance criteria
Aluminium chlorohydrates	<i>Visual</i>	Clear, colourless liquid
	<i>Specific gravity</i>	1.32–1.35 at 25°C
	<i>pH</i>	3.5–4.5
Aluminium sulfate (alum)	<i>Visual</i>	Clear colourless to pale brown (free of solids)
	<i>Specific gravity</i>	1.28–1.34 at 20°C
	<i>pH</i>	2.3–2.8
Ammonia	<i>Visual</i>	Colourless gas or liquid
	<i>Specific gravity</i>	0.8 as a liquid
Ammonium sulfate	<i>Visual</i>	Off-white crystal
	<i>Specific gravity</i>	1.77 at 20°C
Calcium hydroxide (hydrate lime)	<i>Visual</i>	Soft, white crystalline powder
	<i>Solubility</i>	0.165g/100g of saturated solution at 20°C
	<i>Bulk density</i>	450–560 kg/m ³
Calcium hypochlorite	<i>Visual</i>	White crystalline solid, practically clear in water solution
	<i>Specific gravity</i>	2.35 in liquid
Calcium oxide (quick lime)	<i>Visual</i>	Grey-white solid (sometimes yellowish to brown)
	<i>Specific gravity</i>	3.2 – 3.4 as calcium hydroxide
	<i>Bulk density</i>	1 030 kg/m ³ (pebble); 1 050 kg/m ³ (powder)
Carbon, powder activated, granular activated (PAC/GAC)	<i>Visual</i>	Black solid (PAC 20-50 µm; GAC 0.7 – 1.2 mm)
	<i>Density</i>	250–600 kg/m ³
<i>Copper sulfate</i>	<i>Visual</i>	Blue crystal, crystalline granule or powder
Ferric chloride	<i>Visual</i>	Brownish-yellow or orange crystalline form
	<i>Specific gravity</i>	42% solution: 1.45 at 20°C
	<i>pH</i>	42% solution: 1–2
Ferric sulfates	<i>Visual</i>	Yellow crystal or greyish-white powder, or a red-brown liquid solution.
	<i>Specific gravity</i>	Liquid solution: 1.5–1.6

Table 8.3 Acceptance criteria for some water treatment chemicals (continued)

Hydrochloric acid	Visual	Clear colourless to clear yellow (free of solids)
	Specific gravity	28% solution: 1.14 at 20°C
Hydrofluorosilicic acid (fluorosilicic acid)	Visual	Colourless to pale yellow liquid
	Specific gravity	22% solution: 1.18 at 20°C
Hydrogen peroxid	Visual	Colourless syrupy liquid (concentrations from 20% to 60%)
	Specific gravity	1.07–1.24 at 20°C
	pH	1–4
Hydroxylated ferric sulfate	Visual	Translucent, dark red (free of solids)
	Specific gravity	1.45–1.6 at 25°C
	pH	< 2
Polyacrylamides	Visual	White crystalline solid, supplied as a powder or aqueous solution, dispersed in light mineral oil
Polyaluminium chlorides (10%)	Visual	Pale yellow, slightly cloudy liquid
	Specific gravity	1.18–1.22 at 20°C
	pH	10% solution: 2.2–2.8
Polyaluminium silica sulfates	Visual	Slightly cloudy liquid, clear to yellow (free of solids)
	Specific gravity	1.32–1.36 at 25°C
	pH	2.8–3.6
Potassium permanganate	Visual	Odourless, dark purple crystal with blue metallic sheen
Sodium aluminates	Visual	White powder, or clear colourless to pale amber liquid
	Specific gravity	Liquid solution: 1.4–1.6
	pH	Liquid solution: 1.4
Sodium bicarbonate	Visual	White powder or crystalline lumps, soluble in water (60 g/L at 20°C)
	Specific gravity	2.159 at 20°C
	Solubility	96 g/L at 20°C
	Bulk density	1000 kg/m ³
	pH	10 g/L solution: 8.4
Sodium carbonate (soda ash)	Visual	Greyish-white powder
	Bulk density	1000 kg/m ³ (dense); 500 kg/m ³ (light)
Sodium fluoride	Visual	White, odourless powder (or crystal), easily soluble in water
	Specific gravity	2.78 at 20°C
	Bulk density	1040 – 1440 kg/m ³
	pH	1% solution - 6.5 4% solution - 7.6
Sodium fluorosilicate	Visual	White or yellowish white, odourless, crystalline powder
	Bulk density	880 – 1150 kg/m ³
Sodium hexametaphosphate	Visual	White granular powder
	Bulk density	800–1500 kg/m ³
Sodium hydroxide (caustic soda)	Visual	White, deliquescent solid)
	Specific gravity	30% solution: 1.33 46% solution: 1.48
Sodium hypochlorite	Visual	Pale yellow green
Sodium silicate	Visual	Lumps of greenish glass, white powders of varying degrees of solubility, or cloudy or clear liquids of varying viscosity
Sodium tripolyphosphate	Visual	White powder or granular solid
	pH	9.8 (aqueous solution) to 10.5 (slurry)
Sulfuric acid	Visual	Dense, oily, colourless to dark brown liquid.
	Specific gravity	1.2–1.85 at 20°C
Zinc orthophosphate	Visual	Clear odourless liquid

8.8 Contaminants in drinking water treatment chemicals

All chemicals used in the treatment of drinking water should be evaluated for potential contaminants and limits should be included in the specification. The fact sheets for the individual treatment chemicals (see Section V) identify potential contaminants for each chemical. Additional information may also be available from suppliers' specifications or from certification analyses that have been performed for overseas accreditation systems.

The determination of contaminants in drinking water treatment chemicals should be carried out by an independent laboratory accredited to undertake the necessary assays. An appropriate laboratory approved by National Association of Testing Authorities (NATA) should be identified, in consultation with the relevant State or Territory regulatory authority. A list of NATA-approved laboratories is available online².

In developing appropriate specification limits for contaminants a more detailed systematic assessment of potential contaminants using a Recommended Maximum Impurity Concentration (RMIC) approach is recommended. The initial approach uses the principle that no contaminant in a particular chemical should add more than 10% of that allowable by the NHMRC *Australian Drinking Water Guidelines* health value. For each contaminant, this involves:

- calculating from the health guideline value the maximum concentration allowable in the treated water as a result of being dosed with the bulk chemical. In some situations a stricter value than the health guideline may be warranted if the contaminant is known to cause aesthetic problems or the water authority wishes to carry a lower risk level.
- Based on the expected maximum dose of chemical and its strength, calculate the RMIC for each contaminant (mg/kg of solution).

A sample calculation for determining the RMIC of lead in Alum is provided in Box 8.3.

Box 8.3 Sample calculation for determining the lead recommended maximum impurity concentration in Alum

The following is a sample calculation for the derivation of a Recommended Maximum Impurity Concentration (RMIC) for lead in Alum and is based on the NHMRC guideline value for lead in drinking water of 0.01 mg/L. The maximum amount of lead (in mg/L) that may be added to drinking water through the use of alum is determined through the following three steps:

(1) Derivation of the maximum amount of lead that can be added to drinking water through Alum:

$$\frac{0.01}{10} = 0.001 \text{ mg/L}$$

Where:

- 0.01 mg is the NHMRC guideline value for lead; and
- 10 is the percentage of the guideline value considered an acceptable source of contamination in the drinking water (a safety factor of 10 is considered a reasonable contribution by a given impurity in a water treatment chemical).

(2) Derivation of the amount of Alum that will contain 0.001 mg lead:

In the case of the maximum Alum dose of 80 mg/L⁽¹⁾, with a solution strength of 43 % w/w [Al₂(SO₄)₃·14H₂O]:

$$\frac{80 \text{ mg/L}}{0.43} = 186 \text{ mg}$$

Where:

- 80 mg/L is the dose of the drinking water treatment chemical (e.g. Alum); and
- 0.43 is the solution strength of the drinking water treatment chemical (e.g. Alum – 43%)

(3) Derivation of the RMIC for Alum at the plant:

$$\frac{1 \times 10^6}{186 \text{ mg}} \times 0.001 \text{ mg/L} = 5.4 \text{ mg.lead / kg of Alum solution}$$

Where:

- 1 × 10⁶ is the number of milligrams in a kilogram;
- 186 mg is the amount of Alum solution that will contain 0.001 mg of lead
- 0.001 mg/L is the maximum amount of lead per litre that can be added through the Alum dose

Footnote

- (1) The dose of 80 mg/L alum is based on the water treatment plant being designed to regularly treat dirty water events under an enhanced coagulation mode. If the plant was designed to treat low turbidity water for particle removal only, the maximum alum dose may be as low as 10 mg/L which would give an RMIC of 43.2 mg/kg for lead at this plant.

² http://www.nata.com.au/fs_directory.htm

RMICs calculated by the water authority should be used as the minimum basis for chemical specifications. Water authorities are encouraged to use tighter specification values where these can be easily achieved cost effectively. These calculated RMICs should never be seen as a license to degrade the purity of the drinking water treatment chemical.

To assist water authorities in this process, Table 8.4 contains RMICs for a selected number of contaminants which have NHMRC health guideline values. RMICs have been calculated for some of the more common treatment chemicals, typical maximum dose rates and chemical bulk concentrations. RMICs have not been determined for contaminants which have not been identified in the fact sheet for an individual treatment chemical. Aluminium sulfate has been used to illustrate the principle of applying different maximum doses to determine RMIC.

Some treatment chemicals may also contain known contaminants for which there are only aesthetic NHMRC guideline values. RMICs approach can also be used to calculate these contaminants where appropriate.

Where there is no NHMRC Drinking Water Guideline health value for an identified contaminant, water authorities may be able to determine a RMIC based on a review of overseas drinking water guidelines (eg. WHO, US EPA, EEC, the Chemical CODEX etc). If no RMIC can be calculated from a recognised drinking water guideline value then the principle of due diligence would encourage a water authority to maintain concentrations as low as practicable.

Where suppliers are unable to meet the RMIC, then the water authority should examine what levels of the contaminant are reaching consumers to determine if a higher concentration can be tolerated in the treatment chemical without significantly changing the risk of not meeting the NHMRC Drinking Water Guideline value. This analysis should attempt to identify other significant sources of the contaminant, its variability over time and all expected operational conditions. If a higher contaminant level in the bulk chemical is acceptable (i.e. contributes more than 10% of the guideline value) then water authorities should consider whether there is a need for additional controls specifically for that contaminant in the chemical specification, contractual procurement arrangements, treatment plant operations, and monitoring through to consumers taps.

Table 8.4 Example – some recommended maximum impurity concentrations for some drinking water treatment chemicals

Treatment Chemical	Chemical	IMPURITY												
		Antimony	Arsenic	Barium	Cadmium	Chromium	Copper	Cyanide	Fluoride	Lead	Mercury	Nickel	Selenium	Silver
		0.003	0.007	0.7	0.002	0.05	2	0.08	1.5	0.01	0.001	0.02	0.01	0.1
		NHMRC Health Guideline Value (mg/L)												
		Example doses (mg/L)												
Aluminium chlorohydrate	23	0.7	1.6	161	0.5	11.5	460		345	2.3	0.2	4.6	2.3	23
Aluminium sulfate (Alum)	47	7.1	16.5	1645	4.7	117.5	4700		3525	23.5	2.4	47	23.5	235
Aluminium sulfate (Alum)	47	2.4	5.5	548	1.6	39.2	1567		1175	7.8	0.8	15.7	7.8	78
Aluminium sulfate (Alum)	47	1.2	2.7	274	0.8	19.6	783		588	3.9	0.4	7.8	3.9	39
Calcium hydroxide	99		23.1	2310	6.6	165			4950	33	3.3	66	33	330
Calcium hypochlorite	65		151.7	15167	43.3	1083.3			32500	216.7	21.7	433.3	216.7	2167
Calcium oxide	10		0.1	14	0.04	1			30	0.2	0.02	0.4	0.2	2
Chlorine	100		233.3							333.3	33.3			
Copper sulfate	25.5		178.5							255		510		
Ferric chloride	42	1.1	2.5		0.7	17.5	700	28		3.5	0.4	7	3.5	35
Ferric sulfate	20	0.6	1.4		0.4	1	400	16		2	0.2	4	2	20
Hydrochloric acid	33	19.8			13.2	330				66		132		
Hydrofluorosilicic acid	16		74.7		21.3					106.7				
Hydroxylated ferric sulfate	12.5	0.4	0.9		0.3	6.3	250	10		1.3	0.1	2.5	1.3	13
Polyaluminium chloride	10	0.3	0.7	70	0.2	5	200		150	1	0.1	2.0	1	10
Potassium permanganate	99				198	4950					99			
Sodium fluoride	45	90			60					300				
Sodium Fluorosilicate	60	120			80									
Sodium hydroxide	50	15			10	250			50		5	100		
Sodium hypochlorite	12				8						4	80		
Sulfuric acid	98	58.8	137.2	13720	39.2	980	39200		29400	196	19.6		196	

8.9 Useful contacts

AUSTRALIAN GOVERNMENT

National Health and Medical Research Council
GPO Box 9848
CANBERRA ACT 2601
Tel: (02) 6289 9191
E-mail: exec.sec@nhmrc.gov.au
Internet: <http://www.nhmrc.gov.au>

Australian Safety and Compensation Council (ASCC)
GPO Box 9879
Canberra ACT 2601
Tel: (02) 6121 6000
E-mail: info@ascc.gov.au
Internet: <http://www.ascc.gov.au/>

National Industrial Chemicals Notification and
Assessment Scheme (NICNAS)
GPO Box 58
Sydney NSW 2001
Tel: (02) 8577 8800
E-mail: info@nicnas.gov.au
Internet: <http://www.nicnas.gov.au>

Office of Chemical Safety
Therapeutic Goods Administration
PO Box 100
Woden ACT 2606
Tel: 1800 020 653 (freecall) or (02) 6232 8444
E-mail: tga-information-officer@health.gov.au
Internet: <http://www.tga.gov.au/chemicals/ocs/>

AUSTRALIAN CAPITAL TERRITORY

Health Protection Services
ACT Health
Locked Bag 5
Weston Creek ACT 2611
Tel: (02) 6205 1700
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NT Department of Infrastructure, Planning and Environment
GPO Box 1680
DARWIN NT 0801

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NT Worksafe
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Tel: (07) 3234 0938
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Environmental Protection Agency
PO Box 15155
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Email: csc@epa.qld.gov.au
Internet: http://www.epa.qld.gov.au/about_the_epa/contact_us/

Workplace Health and Safety
Department of Industrial Relations
GPO Box 69
BRISBANE QLD 4001

Tel: (07) 3225 2000
WHS Hotline: 1300 369 915
Internet: <http://www.dir.qld.gov.au/workplace/>

SOUTH AUSTRALIA

Environmental Health Service
Department of Health
PO Box 6 Rundle Mall
ADELAIDE SA 5000

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Environment Protection Authority (SA)
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VICTORIA

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Internet: <http://www.health.vic.gov.au/environment>

Environment Protection Authority
GPO Box 4395QQ
MELBOURNE VIC 3001

Tel: (03) 9695 2700
Internet: <http://www.epa.vic.gov.au/>

Victorian Workcover Authority
Ground Floor
222 Exhibition Street
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Tel: (03) 9641 1555 or 1800 136 089
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WESTERN AUSTRALIA

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NATIONAL ORGANISATIONS

Australian Water Association (AWA)
PO Box 388
ARTARMON NSW 1570

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Cooperative Research Centre (CRC) for Water
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National Association of Testing Authorities,
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7 Leeds Street
RHODES NSW 2138

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Internet: <http://www.nata.asn.au/>

Standards Australia Limited
GPO Box 476
SYDNEY NSW 2001

Tel: (02) 8206 6000 or 1300 65 46 46
E-mail: mail@standards.org.au
Internet: <http://www.standards.com.au/>

Water Services Association Australia (WSAA)
PO Box 13172
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MELBOURNE VIC 8010

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American Water Works Association (AWWA)
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Denver, CO 80235
USA

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Codex Alimentarius Commission
Viale delle Terme di Caracalla
00100 Rome, Italy

Internet: www.codexalimentarius.net/

International Organization for Standardization (ISO)
1, rue de Varembe, Case postale 56
CH-1211 Geneva 20
Switzerland

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NSF International
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8.10 Acknowledgments

The NHMRC acknowledges the support and contributions from Gippsland Water and the Cooperative Research Centre for Water Quality and Treatment in the preparation of this Chapter.

8.11 References

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8.12 Further reading

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DEVELOPMENT OF CHAPTER 8 TO THE AUSTRALIAN DRINKING WATER GUIDELINES

In 1988, the NHMRC endorsed the “*Guidelines for Clearance of Water Treatment Chemicals and Processes*”. These guidelines outlined the data requirements for drinking water treatment chemicals assessment, and provided a standardised approach to the assessment of their safety and efficacy. However, they were not regulatory requirements and relatively few chemicals were evaluated under the guidelines. Since the mid 1990s there has not been a practical mechanism for the national assessment and approval of drinking water treatment chemicals in Australia.

In order to initiate a national approach, in 2000 the NHMRC’s Health Advisory Committee established the Drinking Water Treatment Chemicals Working Party. The primary aim of the Working Party was firstly, to protect public health and the aesthetic quality of drinking water by ensuring chemicals used to produce potable water are safe and appropriate for the purpose, and secondly, to provide the water industry with guidance on drinking water treatment chemicals. The Working Party’s remit was to develop guidelines for the assessment of chemicals used in drinking water treatment processes, to use these guidelines to assess drinking water treatment chemicals, and make recommendations to the NHMRC concerning acceptability of chemicals for treating drinking water.

MEMBERSHIP OF THE NHMRC DRINKING WATER TREATMENT CHEMICALS WORKING PARTY

Prof Michael Moore (Chair)	National Research Centre for Environmental Toxicology
Dr Peter Di Marco	Health Department of Western Australia
Mary Drikas	South Australian Water Corporation
Dr Jim Fitzgerald	Department of Human Services, South Australia
Dr Peter Mosse	Gippsland Water
Colin Nicholson	Sydney Water Corporation
Phil Callan (Secretary)	National Health and Medical Research Council

TERMS OF REFERENCE OF THE NHMRC DRINKING WATER TREATMENT CHEMICALS WORKING PARTY

The NHMRC Working Party on Drinking Water Treatment Chemicals, reporting to the NHMRC/ARMCANZ Drinking Water Review Coordinating Group will:

1. Develop Australian Guidelines for the Assessment of New and Existing Drinking Water treatment chemicals, taking into consideration the NHMRC “Guidelines for Clearance of Water Treatment Chemicals and Processes” (NHMRC 1988) and other national and international guidelines;
2. Develop and recommend ways to implement procedures for the continued assessment and approval of new and existing drinking water treatment chemicals through the NHMRC, including mechanisms for a fee-for-service schedule for new chemicals;
3. Undertake a systematic rolling-revision of toxicology and public health aspects of water treatment chemicals in the existing NHMRC list of approved chemicals, taking into consideration chemical mixtures, aesthetics and chemical by-products;
4. Undertake extensive public consultation to ensure broad community acceptance of a national assessment and approval process; and
5. Develop a dissemination and implementation strategy for the adoption of the approved list of drinking water treatment chemicals.

In order to develop chapter 8 to the *Australian Drinking Water Guidelines*, the Working Party required an understanding and assessment of existing international policies, regulations and guidelines relevant to drinking water treatment chemicals. The Working Party prepared a comprehensive assessment report of a systematic comparative analysis of existing national and international practices, including toxicological assessment reports on a range of drinking water treatment chemicals. The report summarises the regulatory frameworks under which drinking water treatment chemicals are assessed, and describes and compares the policies and procedures used by various national and international organisations for:

- evaluating the public safety of chemicals used to treat drinking water; and
- approving the use of such chemicals.

A copy of the report, *Overview of National and International Guidelines and Recommendations on the Assessment and Approval of Chemicals Used in the Treatment of Drinking Water* is available at http://www.nhmrc.gov.au/publications/_files/watergde.pdf

This report was used by the Working Party as the basis for the development of Chapter 8.

PUBLIC CONSULTATION ON CHAPTER 8 TO THE AUSTRALIAN DRINKING WATER GUIDELINES

Consultation on Chapter 8 included a call for submissions on the draft guidelines in February 2005. The call for submissions was publicised in the *Commonwealth Notices Gazette*, *The Weekend Australian*, and invitations were forwarded to known interested parties through the enHealth Council, the Australian Water Association and Water Services Association of Australia.

All submissions received during the consultation were taken into consideration in finalising these Guidelines. Comments were considered by the relevant working party and the NHMRC Drinking Water Treatment Chemical Working Party.

Submissions were received from the following individuals/organisations:

Mr Tony Griggs	
Mr N. F. McLeod	
Mr G. S. R. Walker	
Mr Eddy Ostarcevic	
Mr Peter L Rome	
Mr David McRae	Water Quality Australia (Barwon Southwest Chapter)
Dr Roscoe Taylor	Dept Health and Human Services, Hobart
Mrs Patricia Wheeldon	
Mr Ken Scifleet	
Mrs Lyn C James	
Mr G. S. Smith	
Mr Philip Robertson	
Mr J. T. Webber	Safe Water Association of NSW
Glenn Collins	Melbourne Water
Mr Rodney Hearne	
Mr Victor di Paolo	Dept Human Services (Victoria)
Ms Anne Woolley	Dept Natural Resources and Mines (QLD)
Tim Nightingale	Hardman Australia
Mr P Dharmabalan	
Mr Colin Nicholson	Sydney Water
Diana Buckland	MCS-Global